GAS BUBBLE TRAUMA IN KOOTENAI RIVER FISH DOWNSTREAM OF LIBBY DAM DURING THE SPILL OF 2006

DRAFT REPORT
October 2006

By:

Brian Marotz, Ryan Sylvester, Jim Dunnigan, Tom Ostrowski
Jay DeShazer, John Wachsmuth, Monty Benner, Mike Hensler and Neil Benson

Montana Fish, Wildlife and Parks
Region One, Libby Area Office and Kalispell HQ

Funded by:
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208
Cecilia K Brown, Project Manager

October 2006

Introduction

In June 2006, the surface elevation of Koocanusa Reservoir in northwestern Montana approached full pool elevation (2459 ft msl) and inflows to the reservoir remained in excess of Libby Dam turbine discharge capacity (approx. 24 kcfs when surface elevation approaches full pool). As a result, the US Army Corps of Engineers (USACE) began routing excess water through the spillways on Thursday, June 08 (Figure 1). By 5:00 PM on June 8, spill caused gas supersaturation in the Kootenai River to exceed Montana's gas saturation standard of 110 percent gas supersaturation for 19 days. By 6:00 PM gas exceeded 124 percent supersaturation through June 16 when spill increased and gas saturation increased to 130 percent saturation (peaked at 131.48 percent) (Figure 2). Gas saturation gradually declined below 110 percent by 7 AM on June 27. Only one gas saturometer was available at the US Geological Survey Station until June 14 when three additional saturometers were installed on the D. Thompson Bridge and one was installed approximately 8 miles downstream of Libby Dam (near the site where old bridge piers were removed; Figure 3). Gas hugs the left bank downstream of Libby Dam for roughly 5 to 8 miles until turbulence distributes supersaturated water across the river. Based on results from spill monitoring during 2002, supersaturated water remains unabated downstream to Kootenai Falls, about 28 miles downstream of Libby dam.

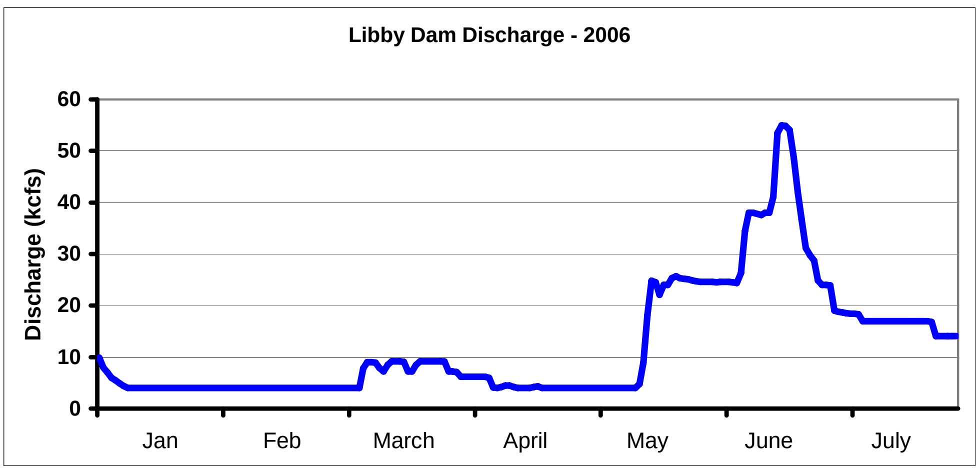


Figure 1. Discharge from Libby Dam into the Kootenai River from January 1, 2006 through July 31, 2006. Maximum capacity through the turbines was approximately 24,000 cubic feet per second during June when the spillway released additional water. Discharge peaked at 54.9 kcfs on June 19th when nearly 31 kcfs was released through the spillway. The spillway was opened from June 8th through June 27th.

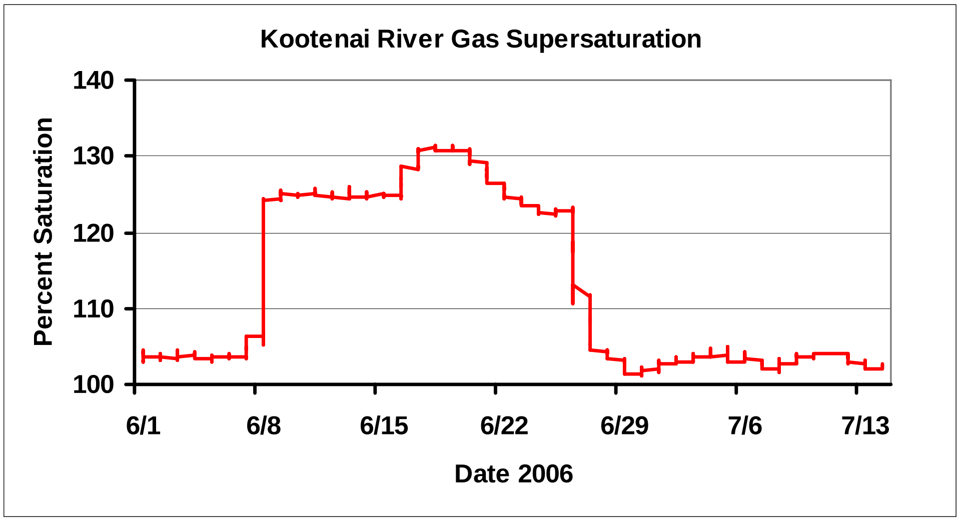


Figure 2. Percent gas supersaturation in the Kootenai River downstream of Libby Dam 2006 as measured at the USGS gauging station. Montana's water quality standard is 110 percent supersaturation.

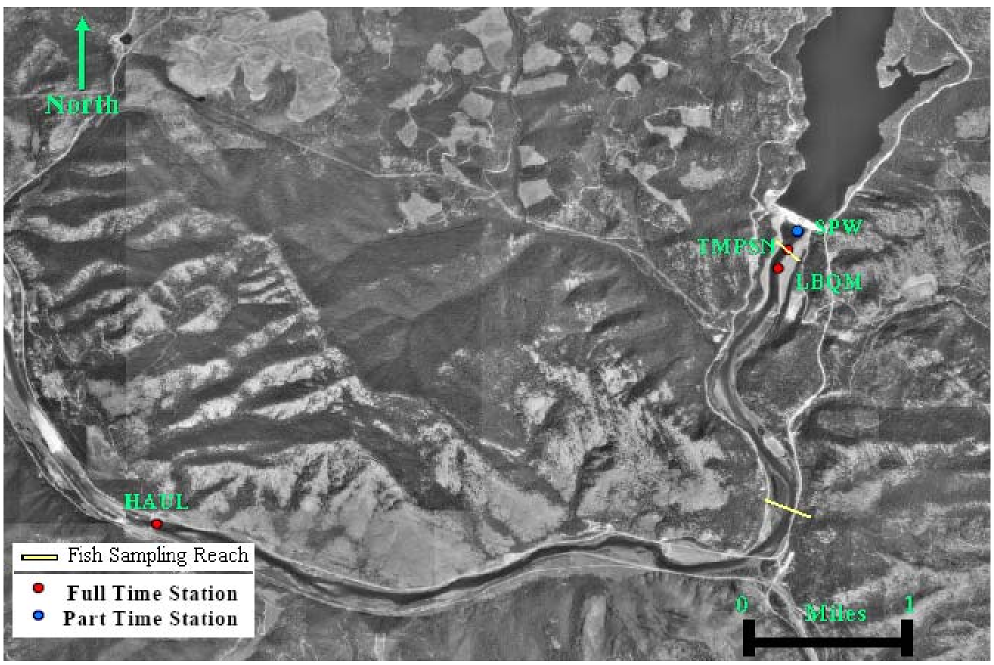


Figure 3. Location of gas saturation readings recorded during the spill event at Libby Dam in June 2006.

Methods

Electrofishing

Montana Fish, Wildlife & Parks (MFWP) used boat-mounted electrofishing apparatus to capture fish in the Kootenai River from the David Thompson Bridge (river mile; RM 221.6) downstream to Dunn Creek (RM 219.8). Electrofishing was conducted at night using a jet boat-mounted Coffelt model Mark 22 electrofishing unit, with an electrical output ranging from 200-300 volts at 5-8 amps. Sampling occurred after dark on June 12,15, 19 and 22. The location of the spillway near the left downstream bank causes a gradient of gas saturation across the river channel in the sampling reach, so personnel examined fish captured along the left and right bank separately. Captured fish were anesthetized fish using an aqueous solution of MS-222. Investigators examined fish for marks, tags, injuries and gas emboli in fins, eyes and external tissues using techniques described by Dunnigan (2003), then recorded anatomical features that exhibited symptoms. During the 2006 spill, GBT was observed in rainbow trout (*Oncorhynchus mykiss*), westslope cutthroat trout (*O. clarki lewisi*), kokanee (*O. nerka*), bull trout (*Salvelinus confluentus*) and Mountain whitefish (*Prosopium williamsoni*). Our reported number of fish with GBT may have been under-estimated because we did not include fish with split fins unless gas bubbles or localized hemorrhaging was also present. Fin splits may be caused by necrosis of the fin tissue between the fin rays resulting from previous injury caused by GBT that had begun to heal (Dunnigan 2003) or may have resulted from physical injury.

Nonlinear regression was used to quantify the potential exposure of fish to super saturated water (days of spill) and relate that exposure to symptoms observed in free-swimming fish that were captured by electrofishing. The percentage of fish showing symptoms of GBT on each sampling night was used as the response variable in the nonlinear regression. In addition, the gas exposure models used by Dunnigan (2003) were also used to assess the impacts of spill on fishes below Libby Dam. The first index was cumulative hourly spill discharge (CSpill) a particular group of fish was exposed to, and was calculated using the following equation.

$$CSpill_j = \sum_i (HSD)$$

Where $Cspill_j$ = The cumulative hourly spill discharge for fish group j at time of examination, and HSD (Hourly Spill Discharge) = the sum of i hourly spill discharge measurements (kcfs) that fish group j was exposed to until examination. For example, if a fish were exposed to 5 kcfs spill for 10 hours, the cumulative hourly spill discharge would be 50. The second index of exposure (CSpWtd) was similar to the previous index, but differed in that it utilized a weighting factor based on the proportion of the spill discharge relative to total discharge. We calculated cumulative spill weighted discharge ($CSpWtd_j$) for fish group j using the following equation.

$$CspWtd_j = \sum_i (\mathrm{HSD})*(\mathrm{HSD}/\mathrm{TD})$$

Where HSD (Hourly Spill Discharge) is the hourly spill (kcfs), and TD is the total discharge at Libby Dam (kcfs) for the i^{th} hourly periods. For example, if a fish were exposed to 5,000 cfs spill with at a total discharge of 10,000 cfs for 10 hours, the cumulative spill weighted discharge would be 25.

Electrofishing surveys will be repeated during fall 2006 to assess changes in fish abundance by length category and species relative abundance and recaptured PIT tagged fishes (i.e., during the spill) can be assessed for healing of previous injuries / trauma from the spill and growth can be assessed.

PIT tagging

Passive Integrated Transponder (PIT) tags were injected in an effort to recapture fish for further examination for secondary infections or latent mortality and to determine if high discharges displaced fish downstream. PIT tags were implanted in muscle tissue posterior to the dorsal fin, adjacent to the vertebra, in all trout ≥300 mm total length using a 12 gauge hypodermic needle. PIT tag models TX1411GL and TX1411SGL from Texas Instruments were used. Prior to injecting tags in each specimen, each tag and needle were sterilized by immersion in Isopropyl alcohol. Once inserted, the tags were read with a Destron Fearing 2001F-ISO portable transceiver and the individual tag number was recorded in the reader, on the data sheet, and on the corresponding scale envelope if applicable. Tagged fish were also marked with an adipose fin clip.

Comment [bm1]: Correct? Ryan, please add details on the type of tag and equipment used.

Gas Bubble Trauma in Kootenai River Fish

After four days of spill on Monday night June 12, 2006, 26 percent of rainbow trout on the downstream left bank had GBT. Six percent of the rainbow trout on the right bank, where gas saturation is lower, had GBT symptoms. Initially, GBT was mainly observed in the fins. Only a few specimens had bubbles in the eyes and gills. Since only 4 bull trout were captured that night, all on the right bank (low gas), no evidence of gas bubble trauma (GBT) was observed in bull trout examined. The frequency of GBT in bull trout increased as spill continued. Thirty-six percent of the whitefish on the left bank and 19 percent on the right bank had GBT. One hundred percent of kokanee captured on the left bank and 20 percent on the right bank had GBT. Dead and dying kokanee were observed; all had physical trauma (scrapes, lacerations, lost body parts etc.), indicating that the fish had passed through the spillway from Koocanusa Reservoir. Remarkably, most of the kokanee had survived passage over the spillway and two kokanee yearclasses; (young of the year (YOY) and age 1+, about 4-5 inches long were observed in the Kootenai River during electrofishing surveys. We discontinued sampling kokanee after the first night and focused on fish species that inhabit the Kootenai River.

Inflow to Koocanusa Reservoir was 39,900 cfs on June 13 and surface elevation was 2457.44 ft, or 1.6 ft from full. As of 10:00 AM on June 14, the National Weather Service River Forecast Center updated their forecast for inflows to the reservoir. Kootenai River stage at Bonners Ferry was 1762.24 feet, 1.76 feet below flood stage (1764 ft). The river was expected to crest at elevation 1764.2 feet during the evening of 15 June. More precipitation was predicted to increase inflows to Libby Reservoir on Wednesday and into Thursday to a peak of near 49,000 cfs and remain at this level through Friday, when inflows were predicted to recede. Based on this forecast, outflow from Libby Dam was expected to remain at 38,000 cfs through the week. In actuality, inflows continued to increase and spill increased to 31,000 cfs in excess of turbine capacity (24 kcfs).

As of Thursday night June 15, after seven days of spill, GBT was evident as bubbles in fins and eyes, external tissue hemorrhages and split fins. Symptoms were common on both sides of the river (at lower spill volumes, supersaturated water flows along the left bank for about 5-8 miles before mixing across). Rainbow trout GBT increased to 68 percent on the left bank and 65 percent on the right bank. Mountain whitefish GBT increased to 62 percent on the left bank and 55 percent on the right bank. GBT symptoms were generally more severe in mountain whitefish specimens. Only 5 bull trout were captured and two had GBT (40 percent incidence).

As of Monday night June 19, 2006, after 11 days of spill, all 16 bull trout captured had GBT. Symptoms included multiple hemorrhages on the ventral surface of the body that appeared as random pinpricks, as well as bubbles in fins, eyes, dermis on the operculum and split fins. Rainbow trout GBT was observed in 67 percent on the left bank and 86 percent on the right bank (an overall slight increase since the night of June 15). Mountain whitefish GBT symptoms increased to 86 percent on the left bank and 80 percent on the right bank. Observation of symptoms and TDG levels recorded by saturometers suggested that supersaturated water may have become more consistent on both sides of the river at higher spill volumes. Gas levels (TDG %) on the left bank were higher than the mid channel and right bank, with approximate mean daily TDG values of 132, 225 and 107% at the highest spill discharge of 31 kcfs (Figure 12). Gas was supersatured nearly 8 miles downstream of the dam, indicating that mixing of water had occurred (Figure 13). Gas levels (i.e., TDG) were 10-15% higher 8 miles downstream than TMPSN3 saturometer values.

As of Thursday night June 22, after 14 days of spill, all 12 bull trout examined had GBT. Ninety-five percent of the rainbow trout on the left bank and 91 percent on the right bank had GBT. Symptoms were observed in 85 percent of the mountain whitefish captured on the left bank and 79 percent on the right bank.

Long-term exposure to gas causes a greater frequency of GBT symptoms with increasing levels of gas supersaturation and repeated exposure as fish utilize shallow river margins. Roughly half of the fish in the sampling reach had GBT symptoms after the first week of spill and the severity of GBT increased over time. Results were used to develop relationships between the duration of spill and the frequency of GBT observed in each species (Figures 4-7 and 8-11). Symptoms in bull trout affected half of the population by the 8th day of spill. After June 19th, the 11th day of spill onward, 100 percent of bull trout examined had GBT. Hemorrhaging on the ventral body surface increased when gas saturation approached 131 percent, then apparently reduced when dissolved gas concentrations reduced toward 124 percent on June 22. It remains uncertain if survivors may have increased susceptibility to secondary complications from external lesions (e.g. split fins, hemorrhaging, abrasions). Weitkamp (1976) found fungal infections were responsible for delayed mortality of juvenile chinook that had survived GBT lesions and hemorrhages near the base of the caudal fin.

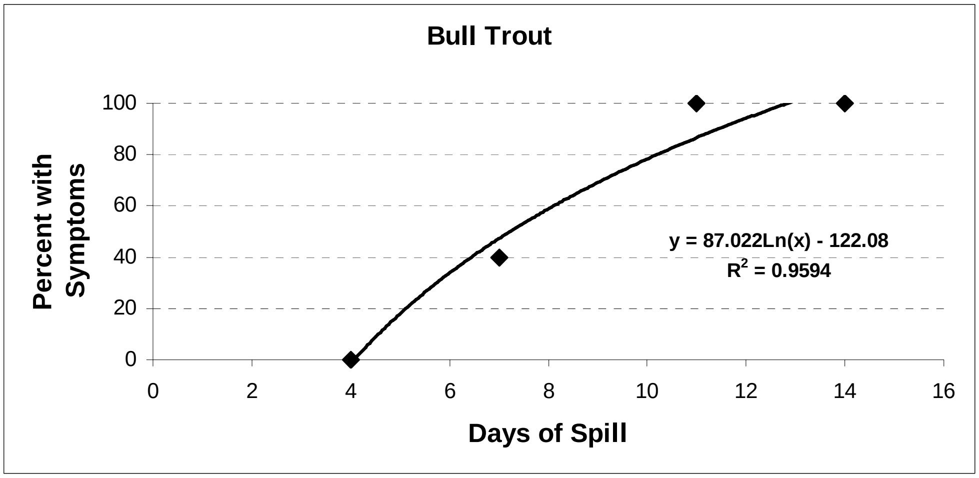


Figure 4. Relationship between the number of days spilled and percentage of bull trout impacted by gas bubble trauma observed during twice-weekly electrofishing surveys, 2006.

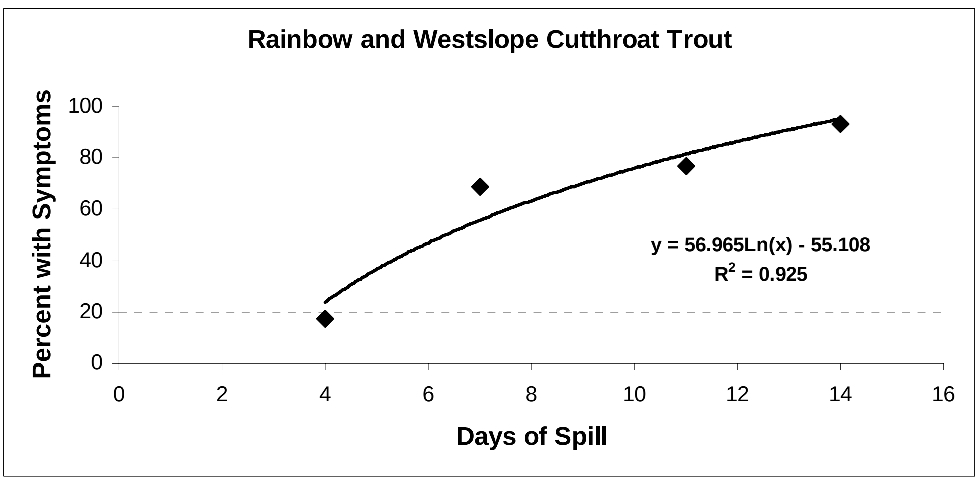


Figure 5. Relationship between the number of days spilled and percentage of rainbow trout and westslope cutthroat trout (data were pooled) impacted by gas bubble trauma observed during twice-weekly electrofishing surveys, 2006.

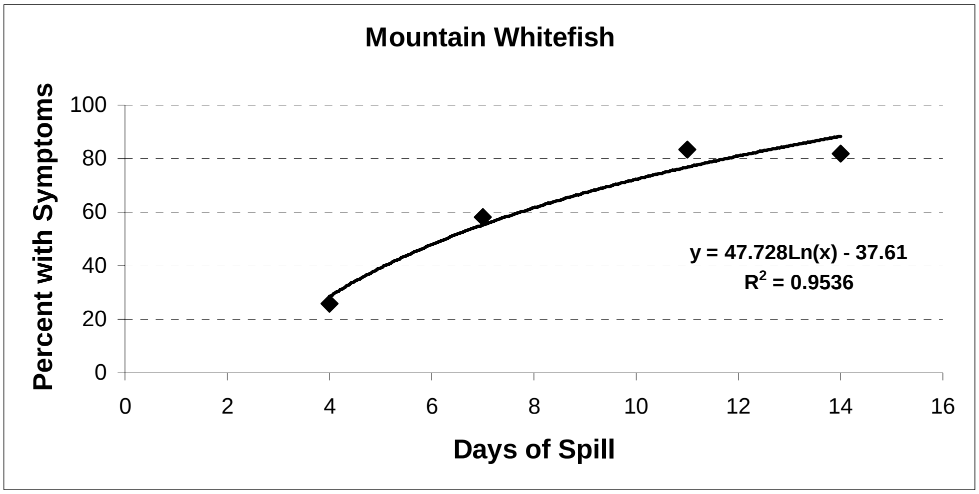


Figure 6. Relationship between the number of days spilled and percentage of mountain whitefish impacted by gas bubble trauma observed during twice-weekly electrofishing surveys, 2006.

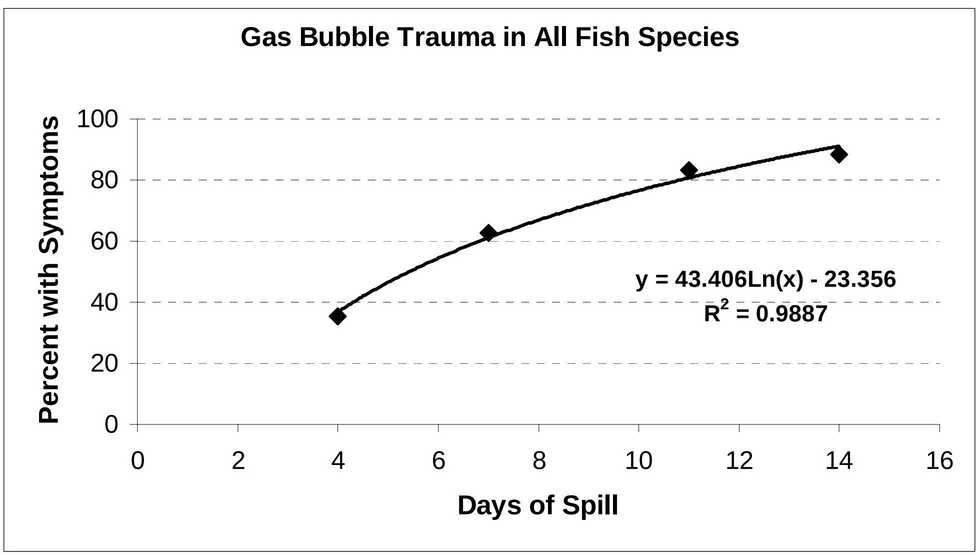
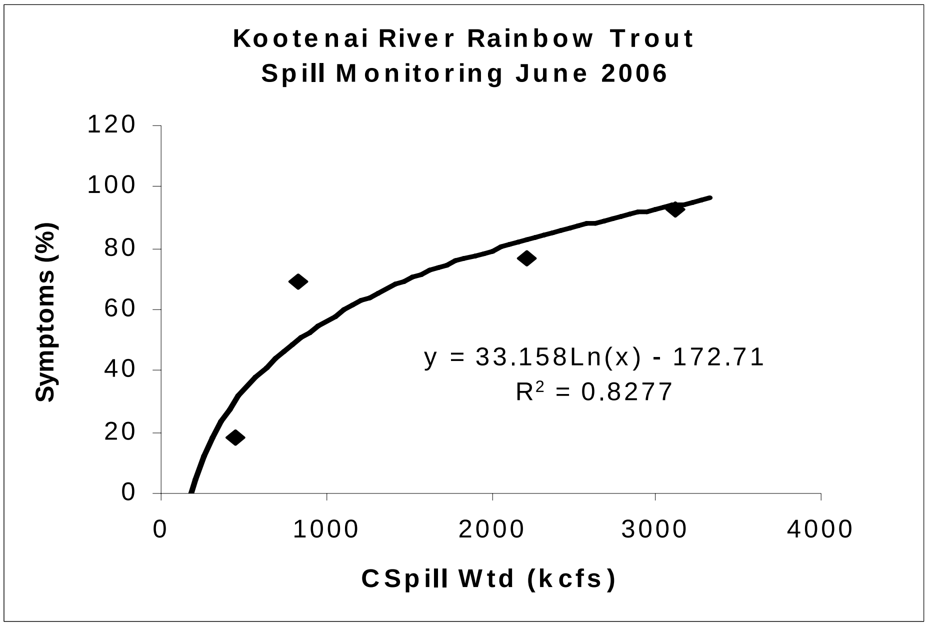


Figure 7. Relationship between the number of days spilled and percentage of fish (all species combined) impacted by gas bubble trauma observed during twice-weekly electrofishing surveys, 2006.



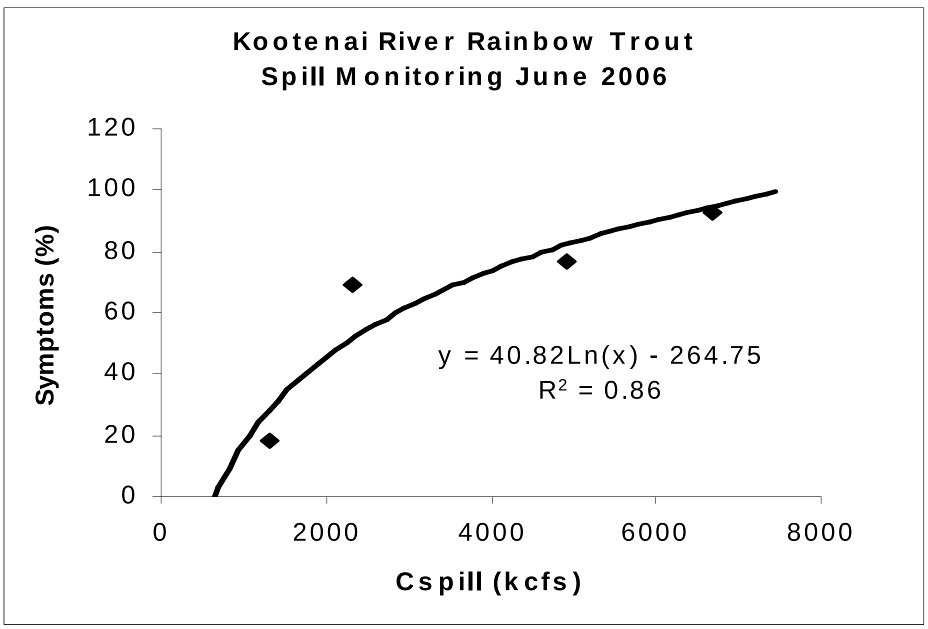
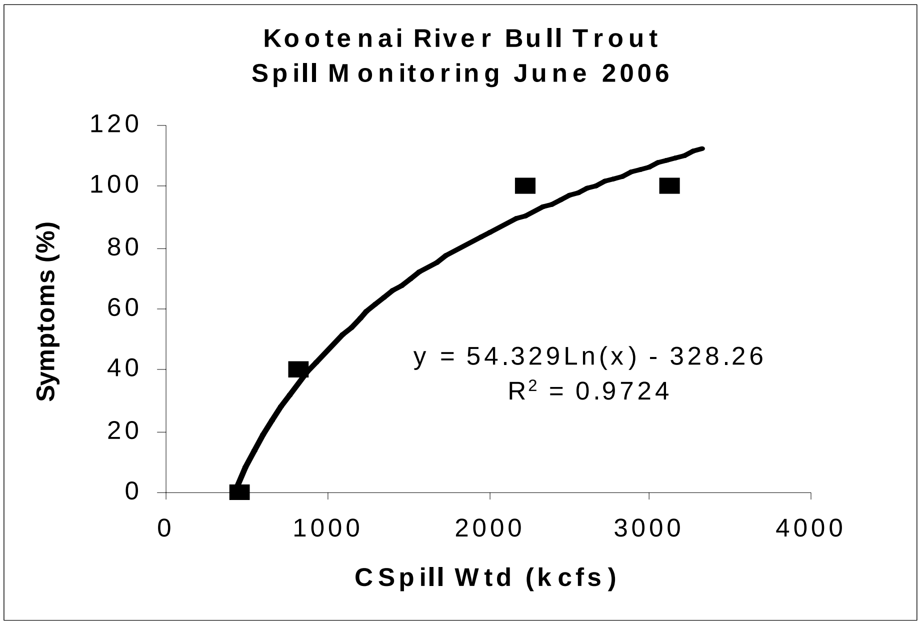


Figure 8. Comparison of spill exposure indexes (CSpill and CSpillWtd, from Dunnigan 2003) in relation to the percent of rainbow trout with gas bubble trauma.



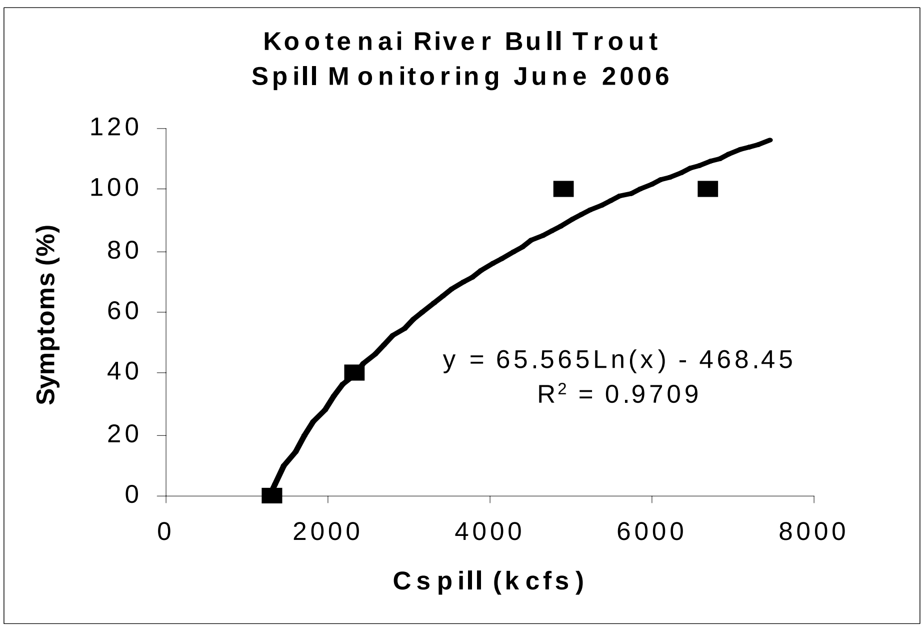
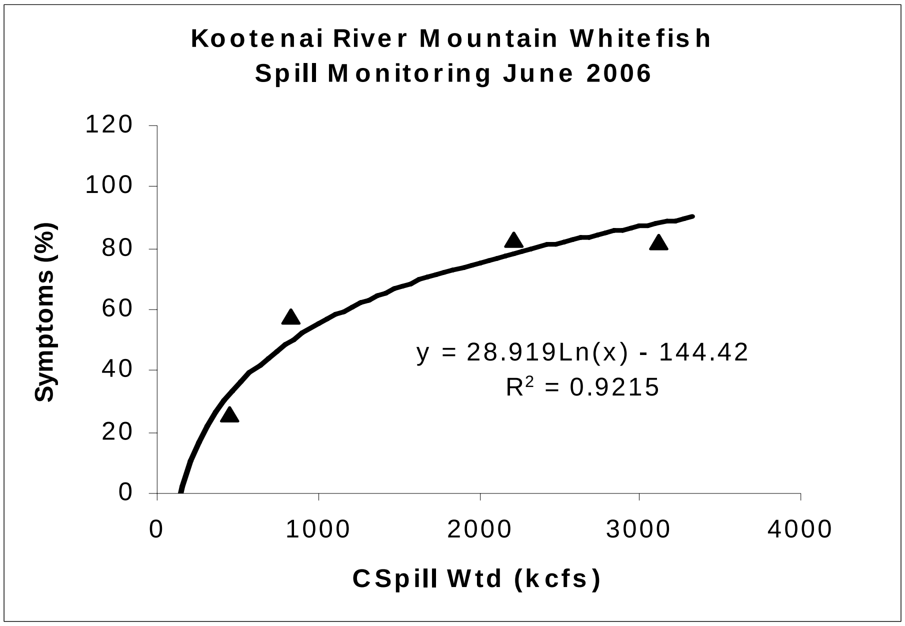


Figure 9. Comparison of spill exposure indexes (Cspill and Cspill WTD, from Dunnigan 2003) in relation to the percent of bull trout with gas bubble trauma.



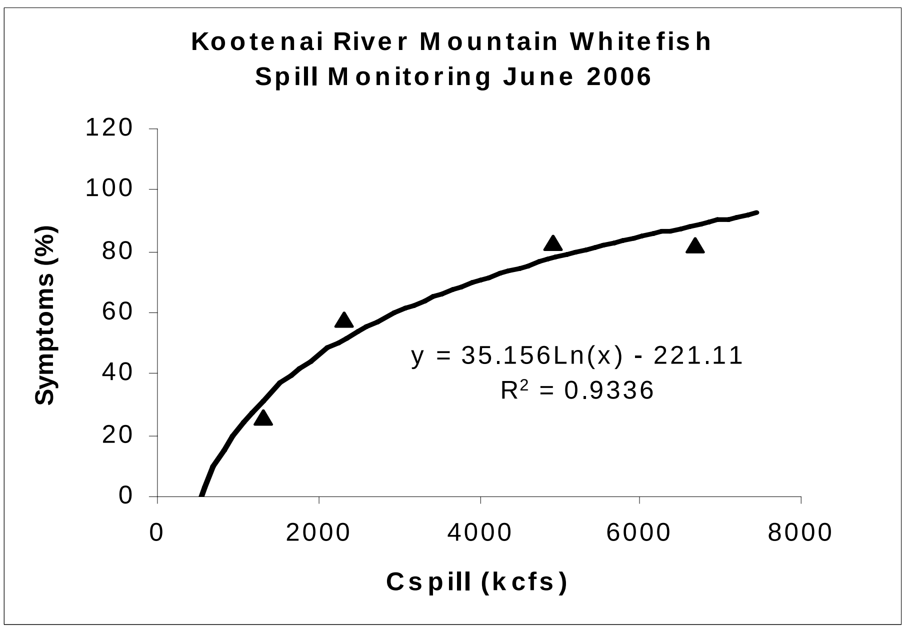
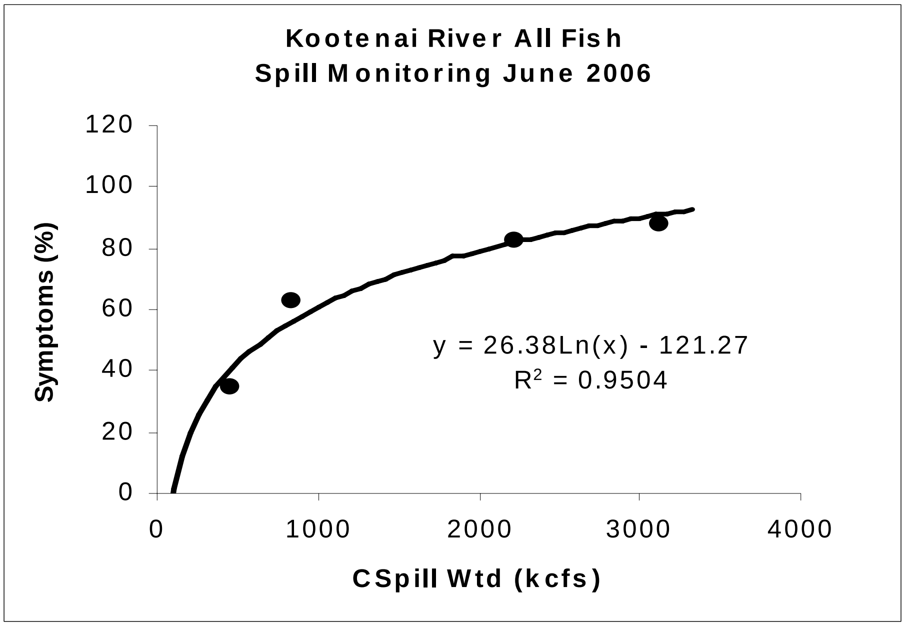


Figure 10. Comparison of spill exposure indexes (Cspill and Cspill WTD, from Dunnigan 2003) in relation to the percent of mountain whitefish with gas bubble trauma.



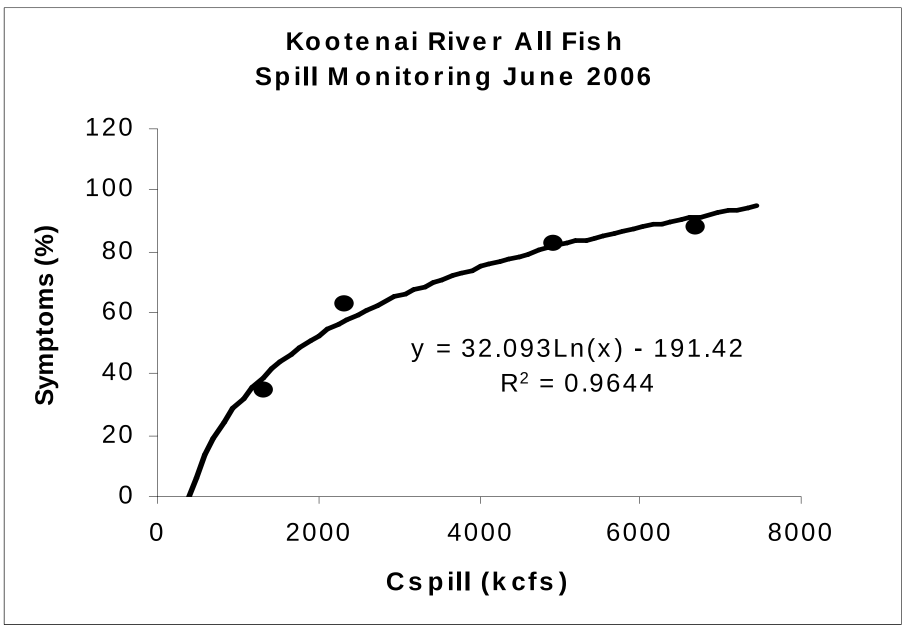


Figure 11. Comparison of spill exposure indexes (Cspill and Cspill WTD, from Dunnigan 2003) in relation to the percent of all fishes with gas bubble trauma.

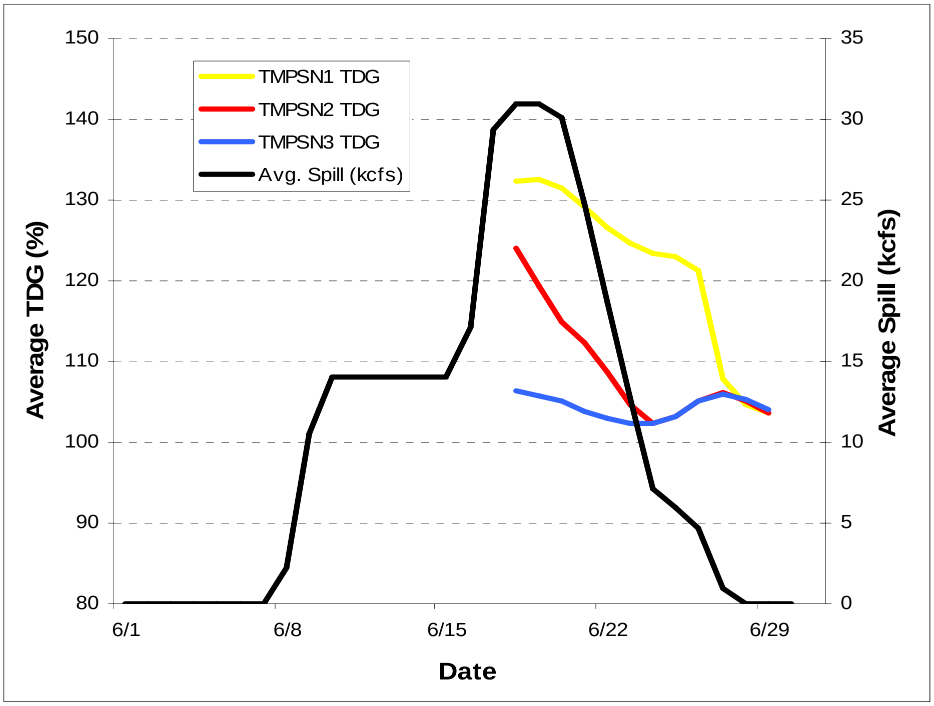


Figure 12. Comparison of gas levels (total dissolved gas; TDG; %) from 3 saturometers located at the David Thompson Bridge located just below Libby Dam. TMPSN1 was located near the left bank, TMPSN2 in the middle of the river, and TMPSN3 was located near the right bank looking downstream.

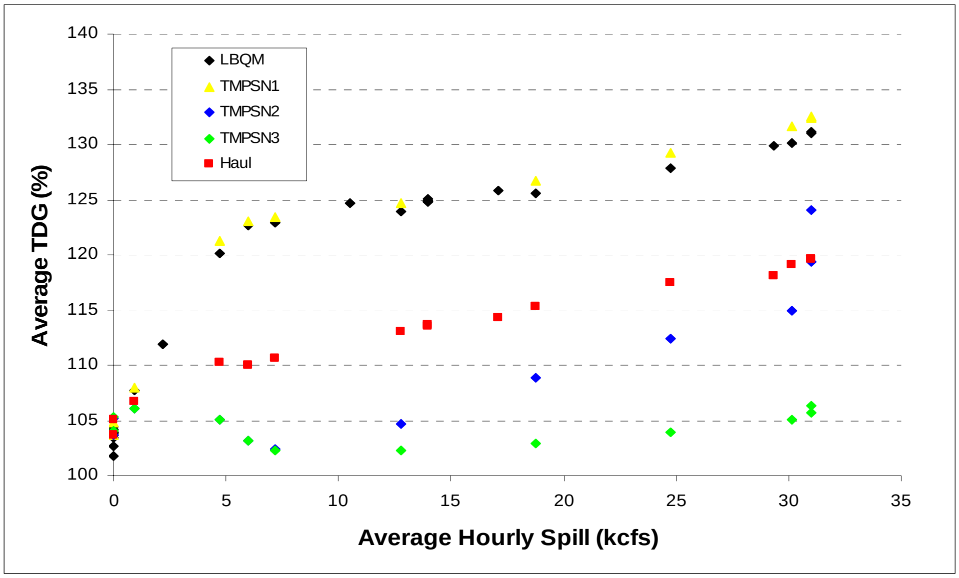


Figure 13. All TDG levels recorded by saturometers located in the Kootenai River in June 2006. Location of LBQM is right below Libby Dam, location of Haul is located approximately 8 miles downstream of Libby Dam, and TMPSN1, 2, and 3, were located on the David Thompson Bridge downstream of Libby Dam.